THE CONQUEST OF OUTER SPACE

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ABSTRACT: Discussion of particular sensations associated with space flight, as well as changes in body functions & blood composition. The OFO-A experiment is described in detail.

After the enthusiasm that followed the exploit by Gagarin, who /63* was the first man in space, and with the end of the "heroic" period where the human being first freed himself from the earth, the space program — considered as a universal enterprise rather than limited to any specific nation — has entered a phase of self-appraisal. At the same time, we are witnessing a more disciplined consideration of the problems and the use of space and violent negative reactions by the common man, as well as by some academic scientific organizations.

We may illustrate some examples of the first case, that is, of the awareness of possible progress, risks, and limits of the new means of transportation.

During the VIII International Symposium of Science and Space Technology, that took place in Tokyo in August, 1969, the Russian physicist Ivanov described a method to maintain physiological levels of water and oxygen in spacecrafts, using cultures of microalgae clorella Interrupting his line of talk with sudden irritation, he said: We should finally decide if it is indispensable to furnish spacecrafts with artificial gravity. How is it possible to design a bioregeneration system for water and oxygen in completely self-sufficient surroundings without knowing if the system will have weight or not?"

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*Numbers in the margin indicate pagination in the original foreign text.

At the beginning of 1967, after the surprisingly faultless series of Mercury and Gemini flights, probably a unique feat in the history of human progress, and after similar good fortune encountered by the Russian counterpart program, three American astronauts died in flames of pure oxygen in the first Apollo capsule that was being tested on the launch pad. Almost simultaneously the Russian astronaut Komarov crash landed with the first Soyuz because of a defective parachute during the capsule descent.

After the sixth Mercury mission, official reports stated that astronaut Glenn had fallen in a bathtub causing an alteration of the internal ear which, although it may not be permanent, certainly is serious. Very recently, during the XIV meeting of COSPAR (Committee for Space Research) in Seattle during June, 1971, we received the news that three Russian astronauts were found dead at the end of a 26-day mission in the space lab Salyut. This occurred after a seemingly perfect reentry maneuver. The cause of this misfortune has not yet been well defined.

Meanwhile, doubts have arisen of whether the American astronauts could not only survive, but also conduct their normal activity in space, at least for the proven limit of 17 days. Even Charles Berry [1], who was then the astronauts' physician, and is now director of the Office of Life Sciences for NASA, after insisting for years that there were no insurmountable problems in space flights, reports in a publication on the data from the Apollo 7-11 missions: "...the capability of more freedom of motion in the Apollo mission cabins compared with the more cramped quarters in other smaller capsules, may be a factor capable of producing motion sickness. The afferent impulses from the semicircular canals that reach the central nervous system during head motions in space seem to increase because of modifications in the activity of the otolithic organ due to weightlessness."

This is an important problem which must always be kept in mind and studied during the space program, because it may significantly alter the astronaut's efficiency."

Among the organism functions studied under these conditions, the one pointed out by Doctor Berry is one of those that have definitely changed. In the field of the sense organs of the nervous system, Gagarin and Titov (Vostok 1 and 2), Glenn (Mercury 6), Schirra (Mercury 8), Cooper (Mercury 9), Nicolyayev (Vostok 3), and above all Yegerov, physician and not astronaut by profession (Vostod 1), and all other astronauts to a greater or lesser extent, had experienced profound sensations of instability, of rotation, and of traveling upside down. Bykowsky (Vostok 5) indicated an impairment of eye motion, and this phenomenon was also observed by Tereshkova, the only woman astronaut, during the same space flight in 1963. Leonov, the first man to walk in space from Voskod 2, did not have any particular complaint during extra vehicular activity, but found himself partially disoriented in the decompression chamber, since in this environment he had no familiar visual stimuli.

For the problems related to the vestibule, discussed by Doctor Berry in the mentioned publication, the manifestations of air-sickness were particularly important, and were found to be very similar to common motion sickness. Even before space flights had started, similar symptoms of more or less pronounced motion sickness were felt by 23 of a 45-man crew in an airplane used for aerobatic flights, where a condition similar to weightlessness was attained during a series of short intervals. Using better airplanes, the percentage was 11 out of 24 subjects. During orbital flights, the classical example was that of Titov, the second Russian cosmonaut, who felt vertigo, nausea, and the sensation that the walls were rotating about him, and that the spacecraft was pitching. Yegerov felt attacks of nausea, like Borman (Gemini 7 and Apollo 8), together with headaches. Schweickart and his crew mates (Apollo 9) suffered nausea and headaches during the first days in orbit. During the Apollo 11 /64 mission, Aldrin, after discontinuing treatment of antikinetic medicine, felt symptoms of motion sickness especially when he moved his head forward; these symptoms disappeared when medication was resumed.

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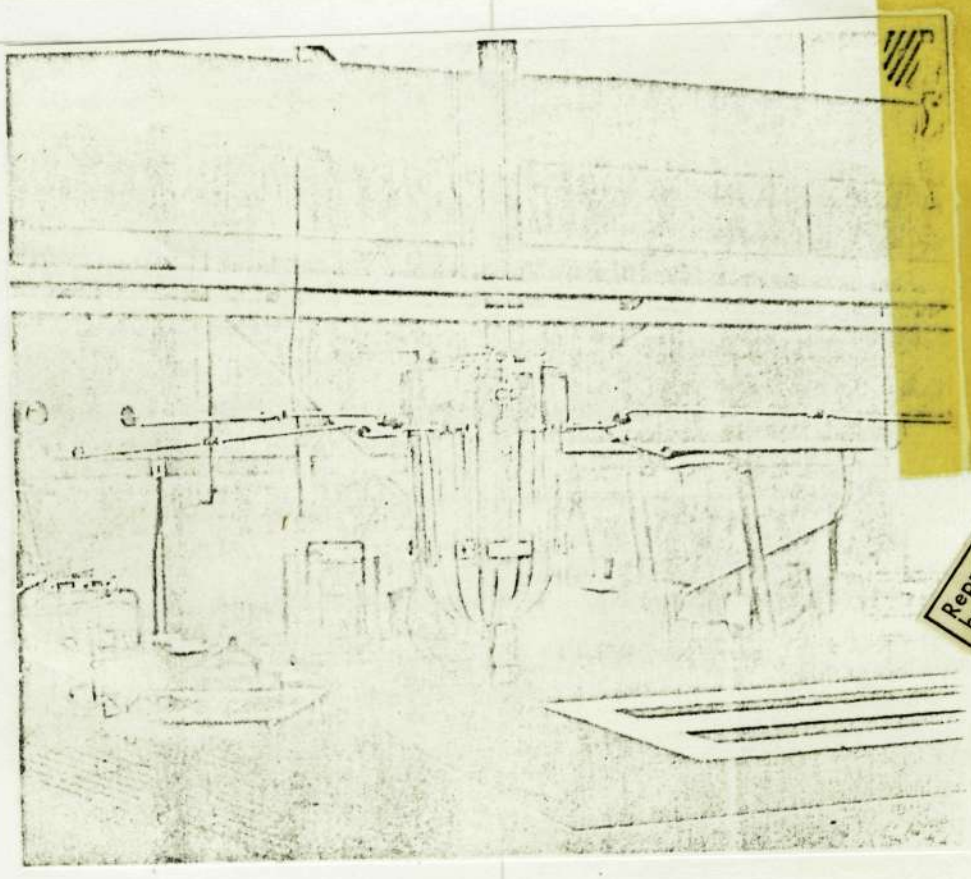

Figure 1. The artificial satellite OFO-A being tested at the NASA base of Wallops Island, Va., with the antennae and the stabilizers open.

During or shortly after orbital flight, the cardiovascular system, the blood chemistry, and the metabolism are all altered as well. The pulse fluctuations and the increase in the duration of the cardiac cycle have been observed in the Mercury as well as in the Gemini programs, and even during the flights of Vostok 6 and Voskhod 1, but the most impressing symptom is the so-called orthostatic intolerance. This consists of the remarkable drop in the arterial pressure when the subject goes from a horizontal to a vertical position, and may even cause unconsciousness in extreme cases. This orthostatic intolerance is experienced after the astronauts have returned to earth, and the longer the astronauts have been in flight, the more severe this phenomenon becomes. After the Gemini 7 fourteen days mission, this phenomenon lasted for 48 hours after reentry. For cosmonaut Borman, a decrease in blood volume was noted, concomitant with a 20% loss of red corpuscles. Immature sub-

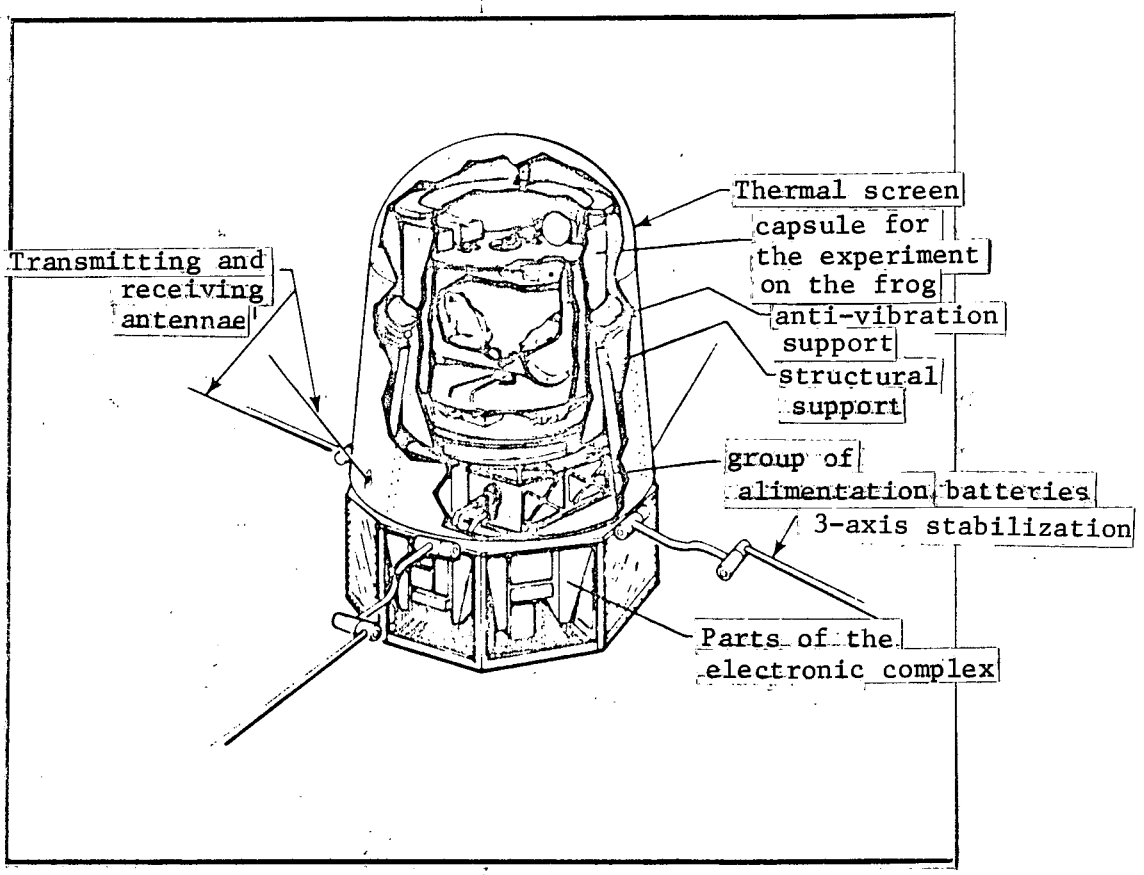

Figure 2. Transverse schematic of the OFO-A satellite containing the space capsule.

stances present in the blood caused a distinct pain in the bone marrow, which produces the new blood cells. From the metabolic point of view, the loss of many of the minerals normally found in the organism, such as calcium, sodium, potassium, and chlorine, was observed after all flights. Even a remarkable loss of water was observed. Other alterations of reduced gravity are due to respiration, which may either decrease, as during the flights of the Mercury and Vostok 3 and 4, or increase, as during the extravehicular activity (Vostok 2 and Gemini 11).

Regarding the second point of this paper, that is, the general antagonism with respect to space, the flights into outer space, and space research, it is obvious that should the human penetration into outer space continue (we refer to permanent orbital laboratories, with up to 56-day shifts for personnel), the problem of going from earth gravity to weightlessness and vice versa without damaging

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consequences becomes increasingly pressing, and should be solved first.

Meanwhile certain opposition has arisen in the public opinion, as well as in certain circles of legitimate science, to spending funds for space research, which is the only way to solve these problems. To quote but one example, Sanders of the Biology Office, Life Sciences, NASA, presented NASA's biological research program in Paris in the spring of this year at the ESRO meeting which representatives from many European nations attended, including members of our National Research Council. The reaction was totally negative, and people were quite angry about the money wasted on the proposed plan of the American agency. /65

We evidently are at a fundamental turning point for science. The dilemma to be considered is: given the high cost of space research and space programs in general, is it convenient to pursue this activity, and, should the answer be affirmative, through which agencies should this research proceed? Consider the comments and reactions regarding what has been defined by the NASA authorities as the first fully successfull biological space experiment, having reached and gone beyond the foreseen objectives. This is the launch of the vestibular experiment OFO-A, that took place September 9 of last year from the NASA base at Wallops, Virginia, USA, using a Scout B. missile (See the article in this publication, No. 6, Nov.-Dec. 1967, pp. 57-60). This experiment may constitute a good example of the pros and cons for biological space programs and their relevance for scientific progress as such, and for the conquest of outer space by man. In fact, the OFO-A had a well defined objective; it has been prepared and executed with extreme care by specialized personnel and with equipment specially built for each purpose, and has provoked reactions that range from total approval to ferocious undocumented criticism. Professor Ades of the Bioacoustic Research Laboratory of the University of Illinois in Urbana, Illinois, U.S.A., defines the experiment such as "to give Italy a unique place in space research." On the other hand, the Committee of Biology and

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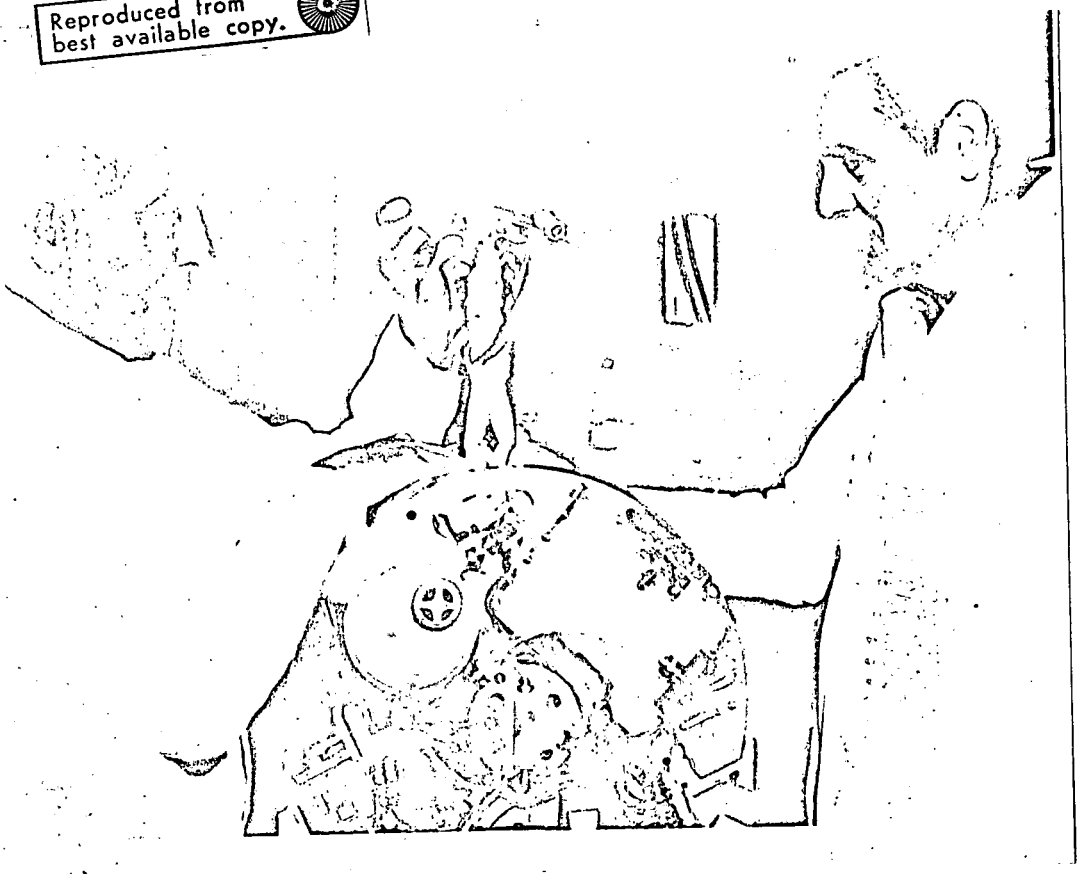

Figure 3. The author of this article and a technician introduce into the space capsule one of the two bull-frogs complete with instrumentation.

Medicine of the CNR considers the project as "not a real scientific problem" and questions wasting the country's resources in such ventures.

I have cited two extremely contrasting sources to indicate the violent controversy that surrounds the whole field of space activity, and especially that of biological experimentation and of man's participation.

A reassessment of the objectives of the OFO-A experiment will allow us to evaluate the results, both in the scientific field and for applications to manned space flights, and thus to present to the reader the general controversy to which we have referred, on the basis of a real example. Within the sphere of the research activity on the internal ear and on its control of equilibrium and of the

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Figure 4. The space capsule, inside an hermetic enclosure, is put on the OFO-A satellite already set on the "nose" of the scout missile in horizontal position.

muscular and visceral system, this experiment had been conceived in order to study the possible behavioral anomalies of the otolith system of single sensors, using a method of direct registration "in situ" on the animal. We should recall Doctor Berry's observations in this subject already mentioned.

A satellite was built for this very purpose capable of keeping the experimental animals alive (in this particular case bull-frogs), as well as to assure a "real" weightlessness state. The component of gravitational attraction would be reduced to such an extent as not to be felt by the most gravity-sensitive elements within the organisms. The details of the biological preparation, of the instrumentation, and method of recording and transmission of the data can be found in the article in this magazine already mentioned. The analysis of both laboratory control animals and results of the six

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and one half days of flight are now being studied. Some fundamental conclusions can already be drawn.

The vestibular organs undergo a noticeable alteration of activity as a consequence of the constant weightlessness. The alteration has a periodic behavior during the first three days of the flight, with increasing tendency to come near the norm; on the fourth day, an excessive compensation is produced, followed, in the next 48 hours, by a slow return to physiological conditions. The whole phenomenon is primarily carried out by the spontaneous activity of sensors. Therefore, it is particularly important for those organs or systems that are controlled by the internal ear, such as the heart, the circulation system, the digestive tract and motion systems, especially those of the eyes. These results represent, even disregarding the specific space program, the first direct investigation of the capacity of a sense organ to modify its function as a consequence of a change of environment, and to gradually get accustomed to it. This is the first investigation which, at the level of the single units that make up an organ, considers the variations corresponding to a learning or training process. The alteration may explain, almost justifying Berry's hypothesis, the occurrence of space sickness symptomology within the first days of orbital flight. Further more, a progressive adaptation is observed which ultimately becomes complete. We may therefore conclude, at least as far as the vestibular function is concerned, that the introduction of artificial gravity in spacecrafts is not indispensable. Should this situation be confirmed for the other systems of the organism, (and this may only be verified by further experiments under conditions of orbital flight), the final conclusion would be that man may adapt to weightlessness and therefore may live in space or on planets with low gravitational attraction. In this case, the physicist Ivanov may design his system of oxygen and water production in a closed cycle within a room having zero gravity.

This, however, does not mean that man can move from earth's gravity to weightlessness and vice versa with impunity. What happens

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when the people who may have lived and worked for a long period of time on spacecrafts on flight to other worlds, or on artificial satellites or orbiting stations, when they finally return to earth? An analogous experiment to the OFO-A, but in reverse, may reveal the behavior of the vestibular organs when we go from zero gravity to Earth gravity. This is the object of a next space flight, a joint Italo-American effort, possibly utilizing the Italian base S. Marco. Very recently this hypothesis seems to have been confirmed by some biological results of the last lunar flight of Apollo 15. This writer was fortunate enought to be able to talk at length, along with about fifteen more Italian scientists, with the three astronauts of Apollo 15, D. R. Scott, A. M. Warden, and J. B. Irwin who had reported a symptomology which agrees with the one obtained in the OFO-A vestibular experiment but seems to confirm the existence of remarkable and prolonged aftereffects after return to earth. Irwin, who had experienced a sense of bewilderment for the first three days of flight to the Moon (see the three days of abnormal activity in the vestibular sensitivity cells of the bull-frogs in the OFO-A experiment) said he felt as though he was reclining by 30° with respect to the horizontal according to the reference points in the space capsule when lying down. While sleeping in a kind of hammock he awoke with the body really inclined by 30°, as if the control center of equilibrium "believed" his new reference point and thus ordered the organism to carry out appropriate modifications in posture. The situation normalized during the following days of flight (see similar data from our OFO-A experiment). After the return to earth, vertigo, bewilderment, and other typical manifestations of motion sickness lasted for as long as 7 days and then disappeared completely.

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This would seem to indicate the existence of posthumous vestibular alterations and the necessity of a certain readaptation period to adjust to terrestrial conditions. Our second experiment (OFO-B) may be able to demonstrate these, as the OFO-A showed for weightlessness.

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If these hypotheses and conclusions are strictly pertinent to the space argument, there are, on the other hand, other more general results which we were able to obtain from the OFO-A experiment. This was a completely automated experiment, which, as already mentioned, lasted six and one-half consecutive days, and which essentially consisted of recording the exact neural activity of single sensors within the vestibular system of the animals maintained under physiological conditions. At the same time, many theoretical problems had to be solved, thus opening new avenues into research on biological phenomena that had been forgotten. Using the same techniques conceived for problems connected with the space experiment, we are now able to study the activity of single elements of any system in normal animals, i.e., animals that have not just undergone surgical trauma, or been subjected to massive distructions. We are also able to build constant environments within reasonable and significant limits for times extending over several multiples of twenty-four hours, which, as is well known, constitute the basic life cycle of all terrestrial life. It is further possible to record biological phenomena without danger of artificial disturbances due to spontaneous mechanical stimuli or those determined by the environment. The animal is free to move about while that particular element of the organism is continusously being analyzed. This has not been possible up to now, and the study of single organs was conducted on animals that were immobilized, or that had recently undergone a more or less destructive surgery, just before the animals died, and for no longer than one or two hours.

In my opinion, the study of the activity of the single chosen elements, at the cellular level of the organism, as a function of time and as a result of an imposed or normal environmental condition is a sufficiently new and important subject in biology to justify the use of funds and human effort characteristic of space projects.

A follow-up study along these lines may not be possible at this time, because of other uses for the funds at our disposal, and, because of that curious phenomenon of mental fatigue that regularly

appears along the great avenues of human progress. During the already mentioned talk with the three astronauts of Apollo 15, Scott, captain of the mission, and undoubtedly the most mature of the three, was asked if he were not disappointed by the imminent cessation of the American program of manned moon exploration, just when such a program was beginning to bring remarkable scientific results. In fact, as is well known, after Apollo 16 and 17 (the latter contains a huge wealth of important experiments, truly a treasure from the scientific point of view) there will be no more flights by the United States to the moon. Scott answered that he was sure that the Americans will return to the Moon, even if many years from now, maybe with more sophisticated and fundamental objectives, up to "colonizing" our satellite. He also observed that the same thing happened in antarctic exploration, which was conducted vigorously up to the first 10 years of this century, to be later abandoned until the present, when such exploration has been taken up more intensely and for more important ends. According to Scott, we will undoubtedly experience a similar phenomenon with the space program, which today is suffering a world crisis.

I would like to conclude on this optimistic note, and, considering our few first steps in outer space of these last 15 years, the reader of today or tomorrow will be able to answer: it was worth it.

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